PIXEL

Reference:

June 2002

Module- cooling support adhesives

Foreword: The aim of this document is to summarize tests done on the final 3 candidates.

Modifications: June17th Wofgang Dietsche

Corrections:

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1. General properties

After a long test protocol, adhesives for the module-cooling support interface have been reduced to 3 candidates: Dow Corning SE4445, Eccobond 45 and CGL7018. Their main properties are summarized in the following table:

General Properties						
VENDOR	**PRODUCT**	**Comments**	**Type**	**No of components**	**Curing time**	**Stated working life[min]**
EMERSON-CUMING	ECCOBOND 45	flexible compound (100 Eccobond+150catalyst)	epoxy	2	16-24h@25C 4-6h@45C	160 (100g@25C)
DOW CORNING	SE 4445	to be used with uballs to achieve the desired thickness	silicon	2	30min@120C (recommanded)	180 (25C)
AI Technology	CGL7018	CGL is used to get the thermal contact; UV tags to get the mechanical action	epoxy paste	1		na

Table1: general properties of the module-support adhesives.

Eccobond 45 is a controlled flexible epoxy adhesive, which can cure at room temperature. Several formulations of flexibilities are available by changing the ratio Eccobond 45 and Catalyst 15. The tests are performed using the most flexible compound.
CGL7018 is a paste that is used to get the thermal contact. Indeed the mechanical adhesion is obtained using UV tacks at the 4 corners of the module. In this case, every test that concerns the mechanical properties of the adhesive should be performed with the UV tacks.
DC SE4445 is a liquid compound that wets very well the applicability surface but it seems very sensitive to the mixing procedure since the two components fastly sediment. Recommanded curing time is 30min@120C which can not be used for our modules, so a study of polymerisation at lower temperatures has been done both in Bonn (see table 2) and in Genova (studying the shear module).

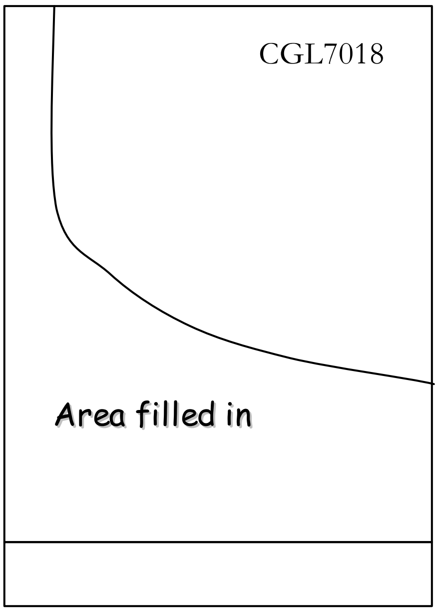
	PART A gr.	**PART B** gr.		**Curing @**	**polimerized**
1	1.01	0.80	- 20%	65°C 5 min	**Yes**
2	1.01	1.20	+ 20%	65°C 5min	**No (pasty)**
3	0.99	0.90	- 10%	65°C 5min	**Yes**
4	1.00	1.10	+10%	65°C 5min	**Yes**
5	1.00	0.95	- 5%	65°C 5min	**Yes**
6	1.00	1.05	+ 5%	65°C 5min	**Yes**
7	1.00	0.90	- 10%	at room 16h	**Yes**
8	1.00	1.10	+ 10%	at room 16h	**Yes**

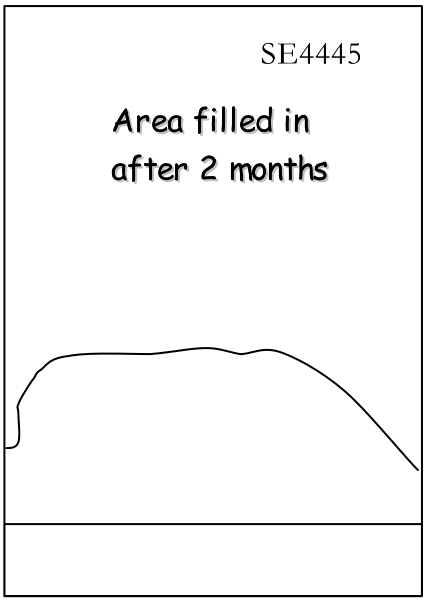
Table2: Curing time and temperature for SE4445 (Bonn)

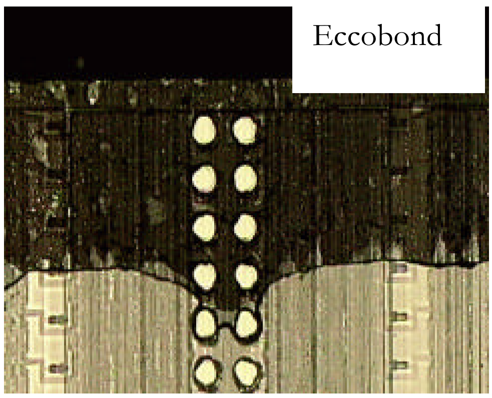
2. Applicability

	APPLICABILITY (details on procedure in Eric documents)				
	Usage life [min] Marseille test	**layer thickness (? m)** If dispenser is used to be verified (Marseille)	**adhesive confined in chip area**	**force needed to achieve a good "wetting" (uniform layer) [g]**	**results & comments**
ECCOBOND	45	100		<100	Easy to manage
SE4445	150	100 (using uballs)	possible by using masks (disks) or optimising deposition procedure as done in Marseille (stave)	<100	UV tacks to be used to prevent module movements during assembly (stave)
CGL	na	100		180	Easy to manage UV tacks needed

Test in Genova have demonstrated that CGL and SE4445 easily penetrates between the FE chip and the sensor. The effect is also present for Eccobond but reduced at the outermost pixel colomns and rows. Typical results are shown in the following figure. Any deposition technique must prevent adhesive to go in the interchip region.

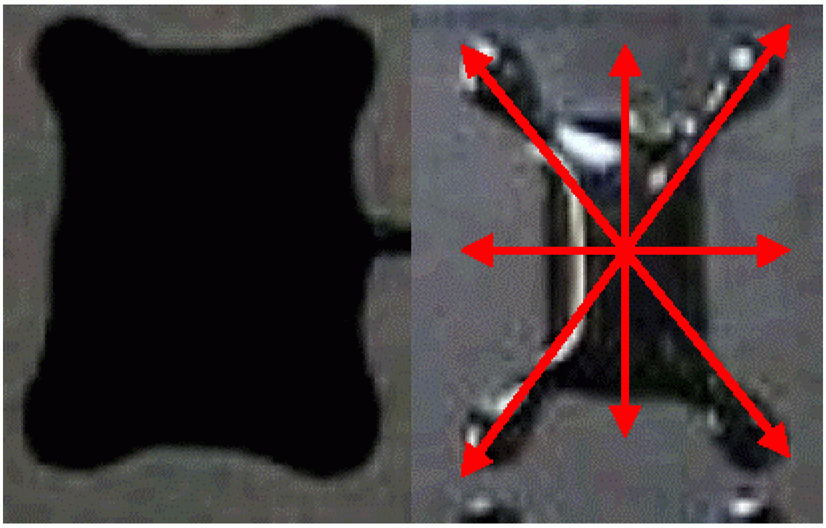






Cross deposition technique:

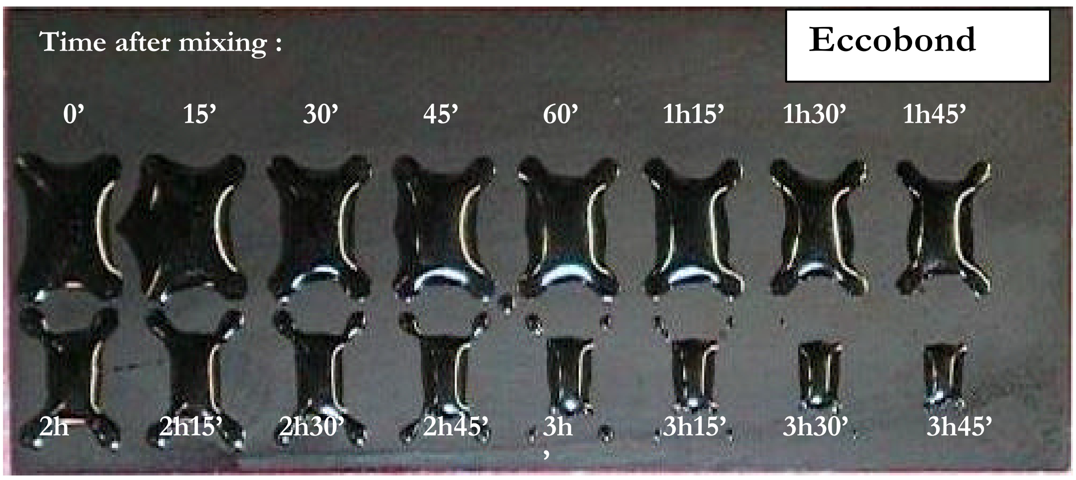
A technique has been optimised in Marseille using a dispenser to obtain a reproducible and confined glue deposition.



On those two picture taken with a fix camera with the same zoom a nd the same resolution, we can observe that the glue expansion during deposition is mainly done in vertical end horizontal direction and not in diagonals ones, as shown in the below picture which is a superposition of the two above ones.
Therefore this technique allows us to control the glue deposition and to guarantee an optimal chip cool down.
The technique has been optimised for the three adhesives; we still have to measure the glue layer thickness obtained for the 3 adhesives (and to monitor the reproducibility) since this parameter strongly influences the thermal conductivity.

Eccobond deposition:

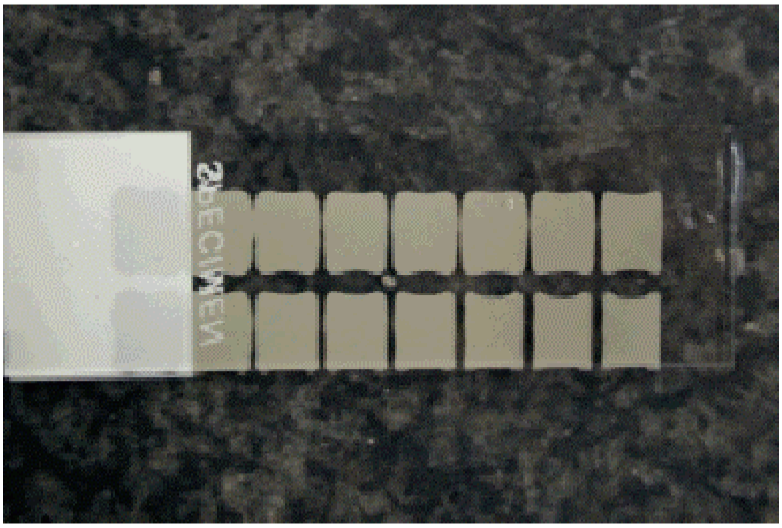
The potting life at ambient temperature after mixture is 3 hours (furnisher data).
While testing different depositions techniques, it appears that the viscosity change significantly during the potting life period.
A simple test was done: it consists to make one cross deposition without changing any parameters (pressure, deposition speed, needle diameter, needle height, shape of the deposition ...) every 15'. The results obtained have shown a quasi-linear variation of the glue viscosity.



Are UV tacks necessary also in this case or is it sufficient to heat locally before releasing the robot head?

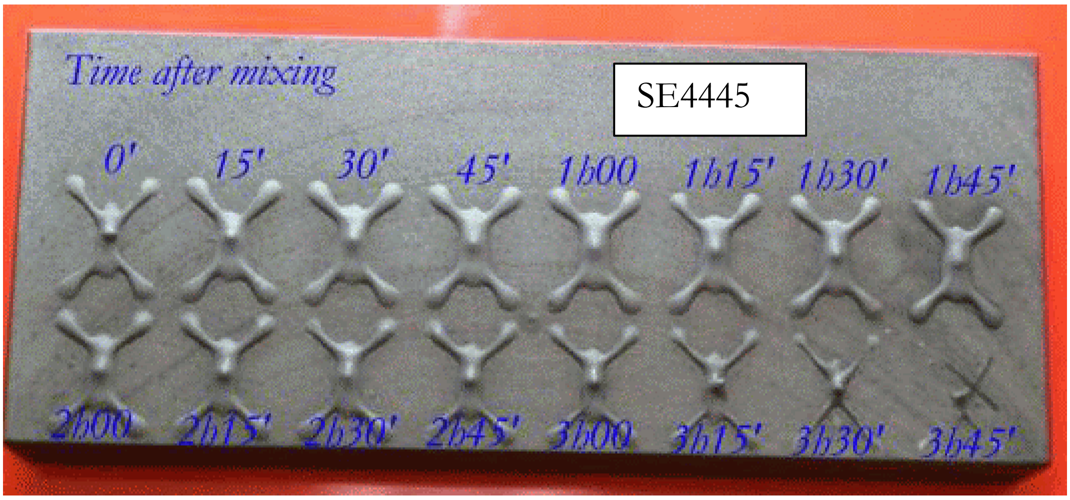
Se4445 deposition:

In the following picture a specimen with an example of results obtained with the cross technique in Marseille is shown.

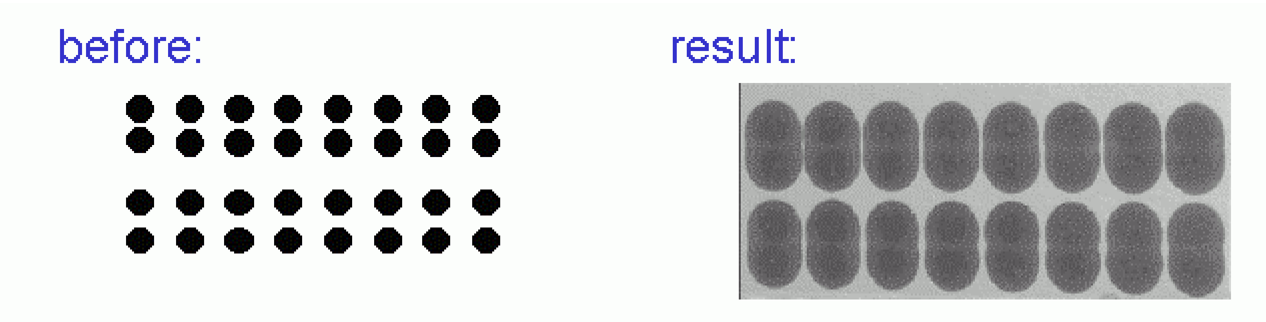


UV tacks during deposition procedure seems necessary to maintain the module in the right position until the polymerisation is completed (Marseille).

This compound behaviour is very different from the Eccobond one. Exceeding the 3 hours of aging, this glue changes quickly its viscosity. The deposition seems to be uniform during 2h30 (with small variations) and remain unusable afterwards.



Also Bonn has studied a deposition technique that allows a very good thermal contact preventing glue to go in the interchip region (the coverage is 70%). This is achieved using a controlled syringe dispenser and a pattern of two dots per chip. Depending on the distance and due to controlled amount of glue, an exact and reproducible pattern of adhesive is made on the surface (see figure).



3. Module removability

The module removability was tested both in Marseille and in Genova. The results show that with the Eccobond 150/100 ratio to remove a module is possible but, as for all the other compounds, not trivial. In Genova a tool to locally heat up to 60C was used: module could be removed without damages of the neighbouring modules (to be verified in real life!).
Se4445 becomes very rigid after irradiation (see shear tests). Will be possible to remove a module after irradiation (if necessary)? It does not seem trivial…

	REMOVABILITY	
	results & comments	**Temperature needed [C]**
ECCOBOND	Possible by locally heating the module	60-70
SE4445	good, critical after irradiation ?	20
CGL	Excellent	20

4. Shear modules

	Shear modulus [N/mm2]		
	Before irradiation	**After irradiation**	**Comments**
ECCOBOND	0.7	7.5	
SE4445	0.06-0.15	0.9-1.9	Shear module strongly depending on mixture procedure and curing temperature
CGL	0.12	?	

SE4445 shear module has been measured with the Genova setup (http://www.ge.infn.it/ATLAS/Test/Adhesives/home.html).
Shear modules can vary in the range 0.16-0.06 according to the curing time and temperature as shown in the following figures/table.
Poor repeatability is obtained and results also depend on the glue samples used. Other tests will be repeated (if necessary) using two original cartridges now in Genoa (all tests have been done with samples from Bonn).
In fig.1 shear modules for glue samples cured at 120C vs increasing time are shown: after 1hour@120C the glue is really polymerised and its mechanical properties do not change any more.

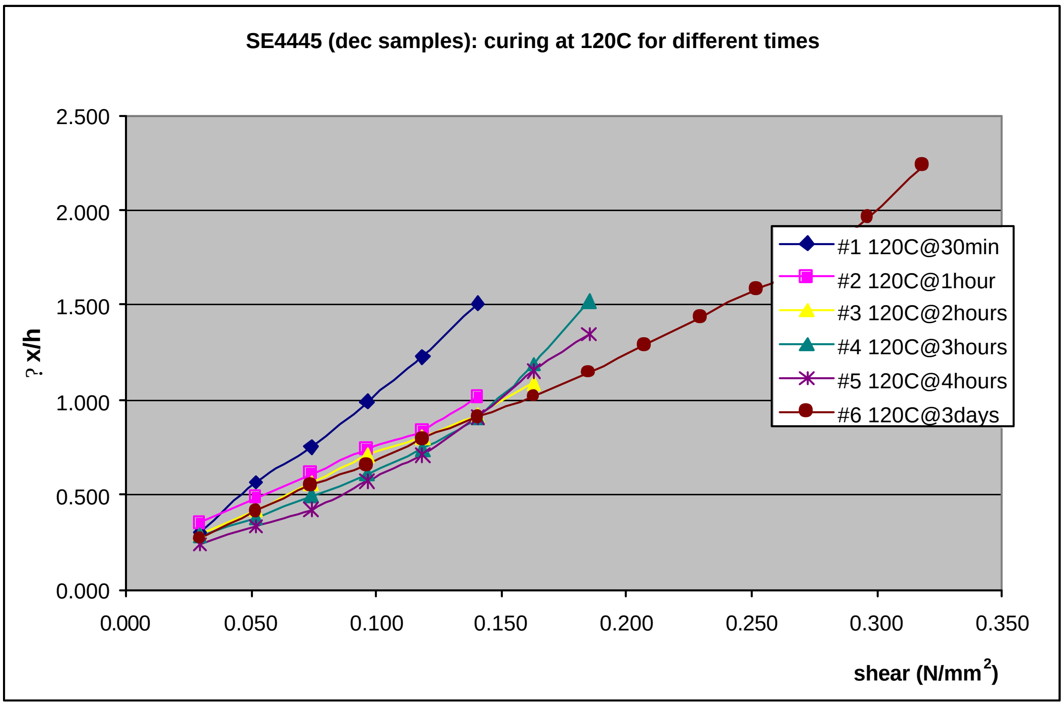


Figure 1

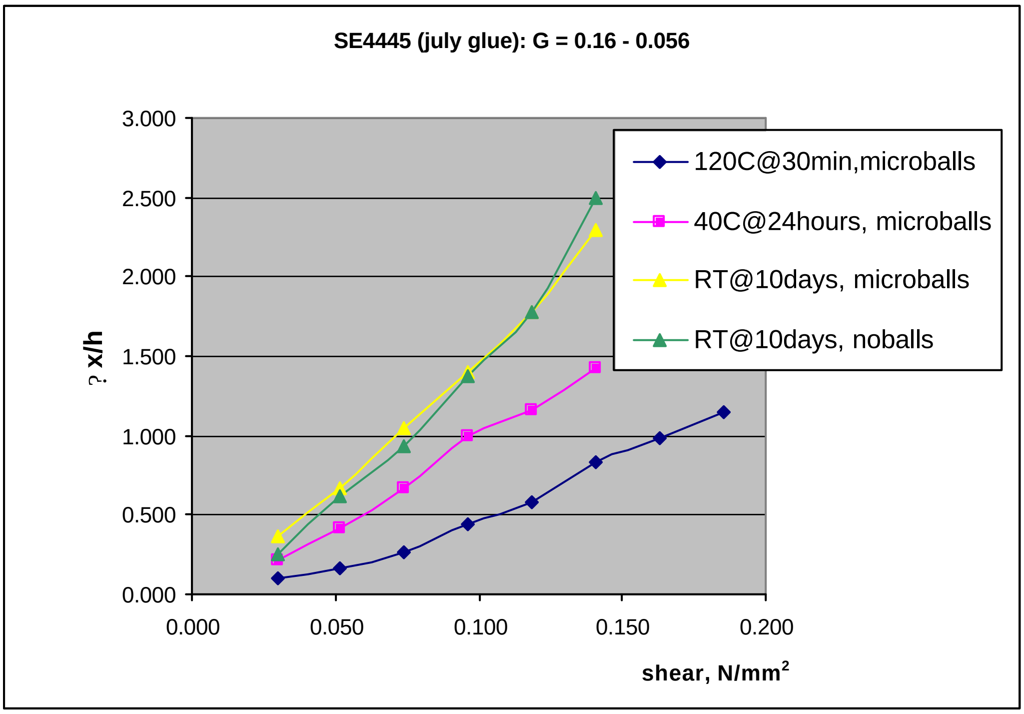


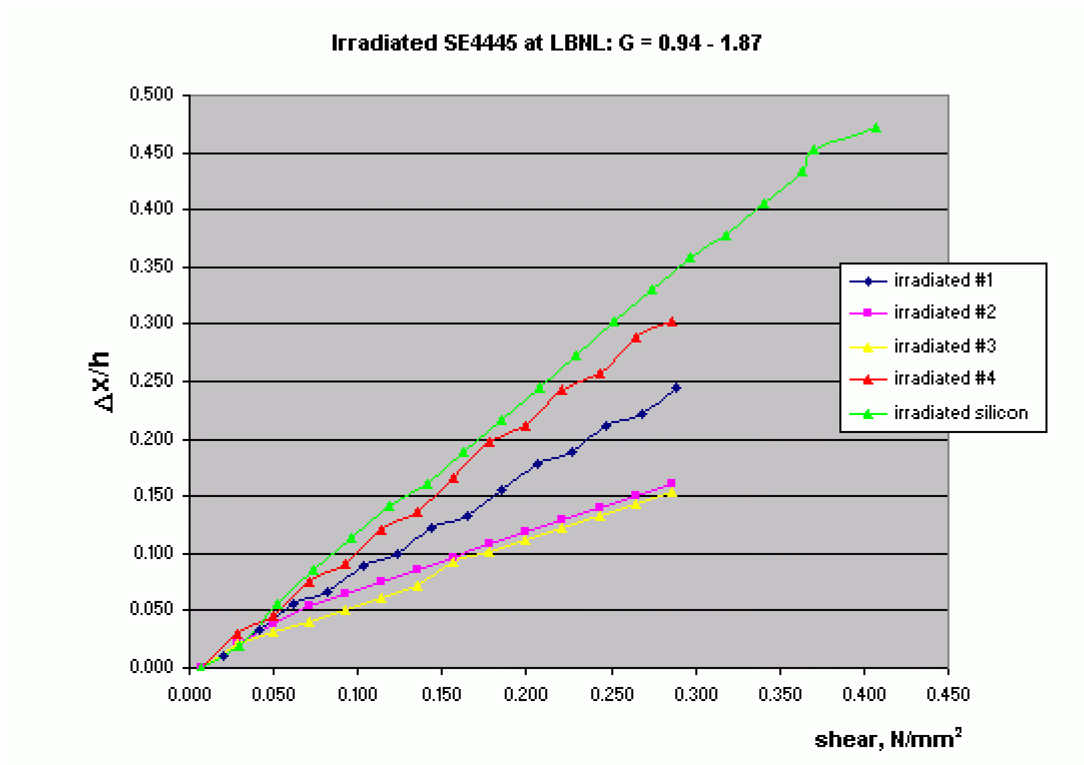
Figure 2

In fig.2, shear modules for different curing temperature are shown: if cured at room temperature the glue is softer and probably polymerisation is not yet complete also after 10 days. 24h@40C seems already sufficient to get an almost complete polymerisation.
10 samples have been used to see how mechanical properties change at room temperature. They have been prepared with the same glue all together (no curing at higher temperature, just assembled and left there): every week the shear module of 2 samples have been measured. In the table, results are summarized:

	samples cured @RT, ? ball			
Curing time [weeks]	Sample 1		Sample 2	
	Fmax [kg]	G [N/mm2]	Fmax [kg]	G [N/mm2]
1	2	na	2	Na
2	9.5	0.106	9.5	0.081
3	9.5	0.115	11	0.105
4	2	na	2	Na
5	11	0.087	9.5	0.073

The shear modules are in the range 0.07-0.12 but no trend is visible and sometimes also a minimum load of 2 kg is sufficient to break the sample and the measure is not possible (marked as na in the table).

Irradiated samples have also been measured (following figure): the glue becomes stiffer and shear modules are in the range 0.9-1.9 N/mm2.

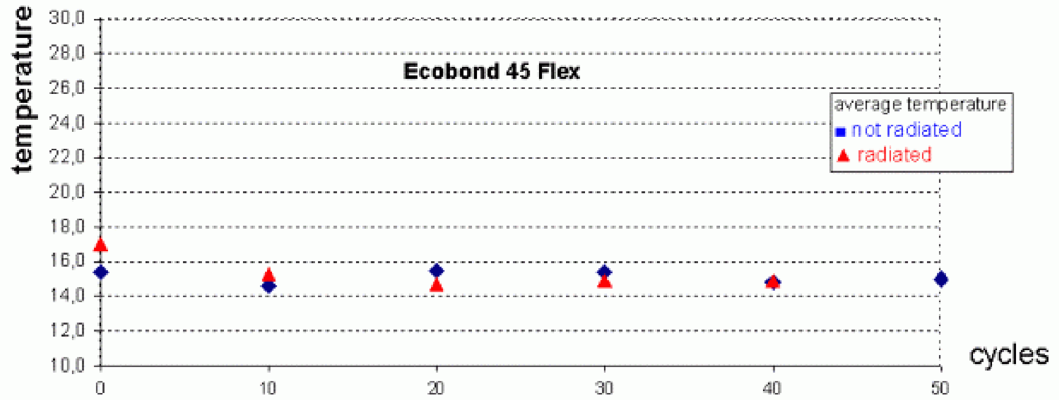


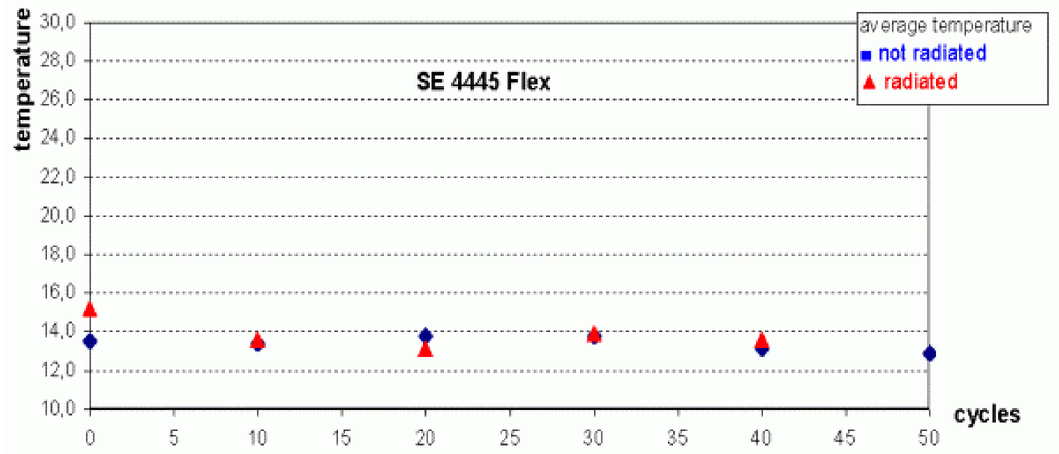
5. Thermal conductivity

	Thermal conductivity				
	Vendor specification (W/mK)	results [W/mK]	results after irradiation [W/mK]	results after aging [W/mK]	test on stave: DT between Si and cooling
ECCOBOND	0.38	~good, comparison w/CGL7018 done (Genoa), 0.22 (Bonn)	unaltered	unaltered	22.3C
SE4445	1.26	0.5	unaltered	unaltered	18.3C
CGL	4.1	0.6	?	Dried but thermally unaltered	11.2C

Tests done with a standard setup (C-C + 100 um adhesive+heater in a bath) in Bonn show that all the 3 adhesives have a comparable thermal conductivity and satisfy our requirements.

The thermal conductivity doe not change also after irradiation as shown in the following plots.





An aging test was performed in Genova (putting samples 10days@120C) and thermal properties remain unaltered (CGL-Eccobond).
Also after thermal cycles thermal conductivity is negligibly altered as reported in the table (measured in Bonn).

	Thermal cycles	
	temperature change after 10 thermal cycles +/- 30 C	**mean temperature on Flex (8 W/module, liquid bath at 10°C)**
ECCOBOND	negligible	14.8
SE4445	negligible	12.7
CGL	negligible	14.6

A thermal test (Marseille) has been performed on a stave, on which Si heaters were assembled using the 3 adhesives with the optimised deposition parameters. 4.5 W were applied on each heater. This test demonstrated that the CGL is the best candidate from the thermal point of view but that the other ones meet our requirements. As the thermal conductivity strongly depends on the adhesive thickness, an accurate measurements of this parameters has to be done while optimising the deposition procedure.

6. Conclusions

The test protocol has allowed to qualify the three candidates and to find out their main limits:
Eccobond: heat needed to remove the module
DC4445: the glue properties strongly depend on the mixture procedure that has to be well under control to get reproducibility. A detailed procedure must be tested to be sure to obtain a mixture with controlled properties (Bonn obtains reproducible results).
Very rigid after irradiation (is it possible to remove it, if necessary?)
CGL7018: it has a volatile component that dries after aging (or in dries atmosphere) transforming the paste into a dry powder. Anyway this effect does not seem to worsen the thermal conductivity (Genova test).